SPECIFICATION

(Attorney Docket No. 99,418)

TO ALL WHOM IT MAY CONCERN:

Be it known that we, **A. Joseph Mueller**, a citizen of Canada and resident of San Diego, California, **Richard G. C. Williams**, a citizen of the United Kingdom and a resident of San Diego, California, have invented certain new and useful improvements in:

HOME NETWORKING
USING
EXISTING DSL EQUIPMENT

the following of which is a specification.

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BACKGROUND OF THE INVENTION

Field of Invention

The present invention relates to communication in home networks. More specifically, it relates to a method and system for using existing digital subscriber line ("DSL") equipment to facilitate home networking between computer devices within a customer premise at a small incremental cost.

Description of the Related Art

Today, a typical family may utilize a number of different personal computing devices. The head of the household may have a computer in the den, study or library to perform work tasks and organize family finances. The children in the household may have their own computer to do homework or play games, surf the Internet and E-mail friends. A printer may be available to handle print jobs. Of course, a number of other peripheral computer devices such as scanners, storage devices, etc. may also be utilized.

To allow these different computer devices to communicate and share information, a local area network ("LAN") may be established between the different computer devices using additional networking equipment. A typical LAN requires a file server workstation or multi-port hub with wired connections to facilitate communication to the various computer devices. These wired connections may require dozens of feet of category 5 shielded twisted pair wire or coaxial cable which must be installed throughout the premises between the different computing devices and the multi-port hub or file server. Each of the various networked computer devices must also have a network interface card to interface to the multi-port hub over the wired connections.

There are also networking approaches that use existing home wiring in order to reduce the expense and inconvenience of using category 5 wiring or coaxial cable. For example, the

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household wiring for telephones and electrical wiring for AC power can also be used for home networking. Wireless techniques can also be used to avoid a change in infrastructure. The current approaches that use conventional telephone wiring to implement networking in the home also share the common feature of using bandwidth that is spectrally compatible with, and separate from, other existing non-network devices that are connected to the phone wiring. In this manner, the home network may run concurrently with these other services. Depending on the particular technique used, the speed of the communication between the interconnected devices will vary.

Even when there is no change in the premise's infrastructure, the additional equipment necessary to implement a home network may significantly increase the cost of connecting just a few computers over a relatively small area. Many households, given the cost and complexity of purchasing and installing a home network, forego the network and tolerate the inconvenience of manually transporting information from computer to computer. Needed is a way to implement networking which minimizes the initial cost and investment required.

A significant effort has been undertaken to use existing telephone lines for high-speed digital data communications. Digital subscriber line ("DSL") is a family of high-speed telecommunication protocols most commonly associated with high-speed digital local loop services provided by local telephone companies. DSL may come in many forms, varying in speed and cost among other factors. The upstream and downstream bandwidths need not be the same. High bit-rate digital subscriber line ("HDSL") and asymmetric digital subscriber line ("ADSL") are examples of DSL variants. All DSL services may be referred to as generic DSL. In a typical DSL configuration, customer premise equipment ("CPE") such as a DSL modem connects subscribers to the telephone companies' central office ("CO"). These DSL modems

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require a small financial investment to purchase, comparable to the cost of traditional voiceband modems.

SUMMARY OF THE INVENTION

The present embodiments offer a lower cost solution to providing network connections between a number of computer devices within the customer premise by using DSL equipment originally intended to provide high-speed digital communications outside the customer premise. Existing home network solutions generally require users to purchase additional networking equipment in addition to existing CPE. The present embodiments leverage the use of existing CPE hardware by enabling DSL modems to also provide network communications between computer devices within the customer premise. Furthermore, with little or no additional equipment or complexity, the CO DSL modem may be incorporated as a separate node of the home network. DSL modems that provide home and small business users faster access to on-line services are becoming more widely used and it is anticipated that modern computers will eventually be equipped with DSL equipment built into the computer. Such DSL equipment is currently designed exclusively to provide high-speed digital communications with the DSL or telephone company central office outside the customer premise.

According to the preferred embodiment, a home networking session establishment sequence is initiated to setup and establish the home networking session using the DSL equipment when the DSL link is idle or under-utilized. According to another aspect of the invention, G.hs protocols are used to establish the home networking session. By specially defining session establishment and physical layer signaling, the present embodiments allow DSL equipment to maintain DSL functionality while also providing a network communications link between computers in a home without requiring additional network equipment.

After the home networking session establishment, DSL signals are transmitted to and from a first DSL device and a second DSL device. The actual signaling may utilize a duplexing

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technique to share the existing DSL frequency band allocation, which may use both the upstream and downstream frequency bands. To ensure DSL connectivity to a central office while the home network is in operation, a DSL device has the ability to resume DSL connections to the central office. The DSL device may monitor the downstream DSL band for initiation tones from the central office to facilitate DSL central office initiated sessions. Similarly, other CPE DSL devices may also initiate DSL connections as further described herein.

According to one embodiment, a home network session between a first DSL device and a second DSL device is established by a request for a special home networking mode such that the central office would not interpret the communication between the first DSL device and the second DSL device as a standard DSL connection. As a result, the existing CPE DSL equipment establishes a home networking session generally independent of the DSL central office. It should be understood, however, that in other embodiments the central office DSL may be configured as a node of the home network. In a particular embodiment, the central office can specifically address one of the CPE DSL modems to establish a home network connection. The home network using DSL equipment can also be provided without a DSL connection to a central office.

By way of example, and without limitation, the invention will be described in the context of an ADSL system. However, the invention may also be suitably employed using other variants of DSL/xDSL (such as HDSL, for example) to facilitate a low cost home network using DSL modems. For instance, DSL modem A and DSL modem B may be interconnected within a home by a user wishing to communicate information from DSL modem A to DSL modem B. According to one application of the invention, if a DSL central office exists then DSL modem A will establish with DSL modem B a session, which the central office DSL equipment will not

confuse with a DSL connection session and may ignore. One or more streams can then be transmitted between DSL modem A and DSL modem B.

Beneficially, a user can use all of his or her existing DSL modems for home networking without purchase of additional home networking equipment. Thus, the present embodiments are an improvement over other existing, more cost prohibitive home network solutions because users need not purchase additional equipment and hardware to implement a home network.

The foregoing as well as other advantages of the present invention will become apparent to those of ordinary skill in the art by reading the following detailed description, with appropriate reference to the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the present invention is described herein with reference to the drawings, in which:

Figure 1 illustrates a DSL home network in accordance with a preferred embodiment of the present invention;

Figure 2 illustrates home networking session establishment in accordance with a preferred embodiment of the present invention;

Figure 3 illustrates a prior art G.lite frequency usage;

Figures 4a and 4b illustrate home networking physical layer signaling using G.lite upstream band and time domain channel separation;

Figure 5 illustrates home networking physical layer signaling using G.lite upstream band and frequency domain channel separation;

Figure 6 illustrates home networking physical layer signaling using G.lite upstream band and channel separation by echo canceling; and

Figure 7 illustrates home networking physical layer signaling using the full G.lite spectrum.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is a schematic of a DSL home network according to a preferred embodiment. In this preferred embodiment, a customer premise includes a telephone 201 connected to a wall socket or POTS outlet 205 providing a RJ-11 jack or similar interface connection. Computer devices 203 are connected to DSL devices 301, 303 to provide communication access to outside the customer premise. It should be understood that computer devices 203 may be a personal computer or any other type of customer premise equipment device that can be interconnected with other equipment or computer peripherals such as storage devices, printers, modems etc. The DSL modem devices 301, 303 are also connected through the POTS outlets 205 to the conventional in-house copper telephone wiring 207 typically used to carry POTS. The customer premise copper telephone wiring 207 typically utilizes 22 to 24 AWG twisted pair wiring. The existing copper wires 207 function as a common communication access line which both interconnects multiple DSL devices and also connects those devices to the local subscriber loop 209 outside the customer premise. The customer premise wiring 207 may also include a splitter to provide isolation and separate voice from data frequencies or an in-line filter between telephone devices 201 and the POTS outlet 205 which are not shown for purposes of clarity of explanation.

The local subscriber loop 209 is terminated at the central office 305 where a central office splitter separates the DSL and POTS frequencies, passing the POTS portion to the PSTN and the DSL portion to a central office DSL device.

The Remote DSL modem devices 301, 303 are preferably ADSL modems. For the purpose of this illustration, it is assumed that G.lite compliant ADSL modems will be used. It should be understood, however, that a variety of other DSL devices could be utilized. In a

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typical ADSL network, a G.lite CPE modem functions as an ATU-R ("Asymmetric Digital Subscriber Line ("ADSL") Transmission Unit-Remote") and communicates with an ATU-C ("ADSL Transmission Unit-Central"). ADSL systems typically use Discrete Multi-Tone Modulation ("DMT") for data transmission. In other embodiments not using ADSL systems, ATU-R modem may be more generally referred to as Remote DSL Modem and the ATU-C modem as Central Office DSL Modem.

Typically, low speed services, such as Plain Old Telephone Service ("POTS"), occupy the lower frequency spectrum from DC up to 4 KHz, while higher speed multimedia services that coexist with POTS occupy higher frequencies. In a DSL home network according to the present embodiment, different remote DSL modems can communicate with each other with or without a central office DSL modem. Preferred embodiments regarding session establishment may include using the ITU Recommendation G.994.1 handshake protocol (also referred to as G.hs) or a specially designed protocol used for signaling such as the one described in more detail below.

Figure 1 shows a schematic of an exemplary embodiment of a DSL home network showing two remote DSL modems 301, 303 or ATU-Rs in this example and one central office modem 305 or ATU-C. It should be understood that additional numbers of devices may also be included. In a typical ADSL configuration, the ATU-R 301, 303 are linked to the CO ATU-C 305 to form a communication loop connected by conventional twisted pair copper wires. The ATU-C 305 may be also integrated within an access node (not shown) outside the customer premise. An access node typically includes digital loop carrier systems such as a Digital Subscriber Line Access Multiplexer ("DSLAM") concentrating individual DSL connections to T1 lines, cellular antenna sites, Private Branch Exchanges ("PBXs"), Optical Network Units ("ONUs") or other carrier systems.

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An ADSL system may also be used with or without splitters. The International Telecommunications Union includes a splitterless standard that is designed to be used without splitters. This "Splitterless Asymmetrical Digital Subscriber Line Transceivers," ITU-G.992.2-1999, is fully incorporated herein by reference. The splitterless ADSL standard is also known as "G.lite." G.lite is a new DSL standard that uses DMT modulation delivering a downstream data rate of up to 1.536 Mbps. An ADSL system may also include one or more splitters (not shown) to separate voice band POTS signals from higher frequency data signals. Other embodiments may use splitters that are well known to those skilled in the art, typically embodied as filters that separate high frequency ADSL signals from low frequency POTS signals. Such splitters may be integrated into the remote DSL modem or central office DSL modem, physically separated from the modems, or divided between high pass and low pass functionality, with the low pass functionality physically separated from the modems.

To transmit data between two ADSL devices, a communications session is first established. The International Telecommunications Union ITU-G.994.1 standard (also known as G.hs mentioned above and fully incorporated by reference herein) defines the handshaking procedures for DSL transceivers to ease session establishment. Once a DSL communication session is established according to G.hs, streams of data are signaled between DSL transceivers.

Figure 2 illustrates a specific embodiment of a method and sequence utilizing the G.hs protocol to establish a home networking session with the ADSL system shown in Figure 1. This particular embodiment includes an active ATU-C 305 capable of providing a high-DSL connection to the central office. In this embodiment, the first ATU-R 301 initiates a network communication session with a responding second ATU-R 303 using a session establishment including the ATU-C 305. The initiation sequence is performed to establish the home networking communication session before any data is transmitted. The first ATU-R 401 of

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Figure 2 initiates the transmission establishing the home network communication session by signaling on the wire connection in general accordance with the G.hs protocol. The ATU-C 403 and any other ATU-Rs 405, including the desired responding second ATU-R 407, receives the initiation signal 409. The ATU-C 403 responds to the initialization signal 409 by returning signaling 411 to the initiating ATU-R 401 indicating that it is capable of negotiating a common communication mode. All other ATU-Rs 405 monitor the G.hs session but remain silent.

In response to the ATU-C 403 signaling 411, the initiator ATU-R 401 then transmits a flag signal 413 indicating that the desired connection is a home network session connection with another ATU-R within the customer premise, rather than a DSL or similar connection outside the customer premise to the ATU-C 403. In this particular embodiment, the flag signal 413 may be implemented using a mode select ("MS") message selecting no common mode and including a non-standard facilities ("NSF") field 415 that contains information unique to the home networking application. For example, the NSF field 415 will preferably contain a home networking mode identifier indicating to the other ATU-Rs 405 that a home network connection session is desired, home networking mode operational parameters such as method of channel separation and timing requirements, and an address or orther identifying information required by the other ATU-Rs 405 to determine which ATU-R 409 should respond to the home network initiation request. In a system with common telephone wiring such as in a typical household or customer premise, the ATU-C 403 (if present) and all the ATU-Rs 405 on the common wire receive the MS with NSF message 415. The ATU-C 403, seeing no common modes and an NSF field not pertaining to DSL session establishment, preferably terminates the G.hs session 417, ignores the NSF field 415 and does not proceed with DSL session establishment, allowing the home networking session to proceed. Alternatively, a new code point in G.hs could be added to specify home networking as a valid operational mode that the ATU-C may or may not support.

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In the present embodiment, a home networking session and DSL connection are not simultaneously established and the idle DSL connection is terminated or powered down during a home networking session. G.lite supports an L3 power-down mode during which a home networking session can be established; however, other quiescent (idle) DSL connection periods can be utilized for home networking as well.

Upon the termination of the G.hs procedure 417, the first ATU-R 401 transmits home networking signals 419 that can be ignored by the ATU-C 403. Meanwhile, the remaining ATU-Rs, having interpreted the NSF field 415, determine if they are the particular ATU-R to respond. When the addressed or second ATU-R 409 determines it is to respond to the first ATU-R 401, it will respond 421 to the first ATU-R's 401 home networking signals 419 and continue with home networking session 423. The G.lite DMT initialization procedure, modulation scheme, framing, error correction techniques and PMD/TC can be utilized for home networking with little modification. The additional signaling requirement for home networking includes the extraction of timing without the downstream pilot (unless the central office continues to provide the pilot during the idle period). If necessary, a trivial solution could utilize DMT carrier 16 to provide pilot when in home networking mode. Depending upon the frequency band selection, the data rates for home networking could be similar to that of a G.lite mode session, i.e., 512 Kbps or more in one direction and 1.536 Mbps or more in the other direction. The communication of the home networking session would proceed as if the connection were a typical DSL connection to the ATU-C. Of course, the application software would also be able to recognize the connection as a home networking connection.

This preferred embodiment is advantageous because of its adherence to the G.hs standard and its ability to provide home networking functionality in the presence of a DSL central office modem.

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It should be understood that according to another embodiment, the central office 305 (Figure 1) may also operate as a node on the home network. The central office ("CO") 305 may also utilize G.hs to specify a network connection from the central office 305 to a particular CPE DSL modem device 301, 303. For example, a "push" technology software application may utilize the CO-DSL modem address capability to transfer information from the CO 305 to a particular CPE DSL modem device 301 or sending an incoming voice-over-IP call to one DSL modem device 301 and an E-mail message to another DSL device 303. G.hs can be utilized by the CO to identify and inform all CPE modems that it wishes to establish a home networking connection to a CPE DSL modem. Using methods similar to that used to connect two DSL modems 301, 303, the CO 305 can establish connection to a particular DSL modem device.

In a particular embodiment, the CO may initiate G.hs in the typical manner described above and wait for any single DSL modem to respond (i.e. contention between multiple CPEs is resolved using 'busy signaling'). Once the G.hs communications link has been established, the G.hs information exchange proceeds as usual, however, an extra field (either a newly defined field or a non-standard field) is utilized to identify to which DSL modem the CO should establish a connection. For example, this identification may be an actual number corresponding to a particular DSL modem. All DSL modems, regardless of whether or not they are the particular modem being addressed by the CO's initiation request, should receive and decipher the CO's G.hs signaling and extract the information from the communication. This is similar to the procedure for home networking session establishment initiated by a CPE described above in that the other DSL modem's always listen to the initiating modem or CO. Typically the initiating device is another CPE modem in the CPE-to-CPE or CPE-to-CO home networking case, but is the CO in the CO-to-CPE home networking case. According to another aspect of the invention, busy signaling indication may be utilized to allow multiple CPE devices to share a

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common communication access line as is found in a home networking application. For example, busy signaling may be utilized to avoid confusion between initiation signals among a plurality of CPE devices sharing communication access on a common wire and ensuring compatibility between a plurality of devices. Busy signaling is further disclosed in U.S. Patent Application Serial No. 09/365,094, "Method and System For Connecting Multiple DSL Modems to a Telephone Line," which is fully incorporated by reference herein.

In another preferred embodiment of a DSL home network, the active involvement of the Central Office DSL Modem for session establishment is not required, a necessity in the case where the subscriber does not have DSL service. In this case, home networking can be established between computer device Remote DSL Modems without the active participation of an ATU-C. Of course, the preferred embodiment for home networking session establishment between an initiating Remote DSL Modem and a responding DSL Modem without a Central Office DSL Modem may differ from the embodiment with an active Central Office DSL Modem. In this Remote DSL Modem embodiment for session establishment without an active Central Office DSL Modem, the initiating first Remote DSL Modem may initiate transmission by signaling on the common customer premise wire in accordance with the G.hs protocol.

To avoid confusion for a Central Office DSL modem that may be present, the G.hs procedure should preferably be performed using a G.hs tone set unique to home networking that does not conflict with typical G.hs tone sets utilized to establish a DSL connection with a Central Office DSL Modem. An example could be using tones 5 and 13 in one direction and tones 21 and 29 in the other direction. It should be understood that tones refer to the DMT tones and that the actual transmitted frequency is the tone number times 4.3125 KHz. With this new tone set, many different alternatives are available. G.hs can be utilized as presently defined with NSF fields as described above, or a new codepoint for home networking in G.hs can be added (ie. use

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a modified G.hs tailored to the home networking application). The additional complexity introduced increases with each deviation from G.hs, however, additional benefits may also be achieved.

Alternatively, in yet another preferred embodiment for session establishment, a signal set that does not correspond to G.hs or other DSL activation signals will be used. The home networking session establishment will therefore not invoke a DSL session establishment response from the Central Office DSL Modem and the home networking establishment negotiations can proceed directly between the DSL modems capable of home networking. This can be accomplished using either a version of G.hs modified to perform MAC functions or an alternate MAC protocol designed to work with such a signal set. To maintain the DSL functionality of the CPE devices, that is the functionality to communicate over a high-speed digital connection to a telephone company central office/ATU-C, the home network can preferably be placed in an idle state.

For example, in a preferred embodiment of a DSL home network, during a home networking session the CPE may detect any downstream signals from the CO in anticipation of CO-initiation tones signaling a DSL connection is desired. The CPE modems may terminate the home networking session allowing the DSL connection to proceed normally as if the home networking capability were not present. With G.lite, the CO initiates a DSL connection using a subset of the DMT tones numbered 40, 48, 64 or 68 (ie. one or more of these tones). By restricting the DSL modems from transmitting on any of these tones when in home networking mode (or transmitting in such a manner that if the CO were to transmit them, it could be detected – i.e., use a low power level) the CO's initiation attempt can be detected. Thus, upon detecting such CO initiation signals, the home networking connection could be dropped to allow the DSL

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session establishment and connection to proceed. Busy signaling can be applicable wherever a DSL connection is being established in the presence of multiple remote DSLs.

A remote DSL modem may also interrupt a home networking connection to start a DSL connection with a Central Office DSL Modem. During a home networking session, the CPE may detect any upstream signals from other CPE devices in anticipation of CPE-initiation tones signaling a DSL connection is desired. The DSL modems performing home networking may terminate the home networking session allowing the DSL connection to proceed normally as if the home networking capability were not present. With G.lite, the CO initiates a DSL connection using a subset of the DMT tones numbered 7, 9, 17, 25 (ie. one or more of these tones). By restricting the DSL modems from transmitting on any of these tones when in home networking mode (or transmitting in such a manner that if a CPE DSL modem were to transmit them, it could be detected – i.e., use a low power level) the CPE's initiation attempt can be detected. Thus, upon detecting such CPE initiation signals, the home networking connection could be dropped to allow the DSL session establishment and connection to proceed

Apart from home networking session establishment, the actual signaling on the common wires utilized to establish home networking may also require special attention to efficiently reuse the DSL signaling frequency spectrum. Efficient reuse of the DSL signaling frequency spectrum facilitates the complete re-use of existing DSL equipment and maintains spectral compatibility with other equipment that may be sharing the wire. Once again, it will be appreciated that though the exemplary embodiment refers to ADSL and G.lite, the embodiments are not restricted to only those illustrations but may extend for instance to other DSL variants in home networking.

Figure 3 illustrates a typical G.lite spectrum where a lower frequency band is dedicated to upstream communication, the upstream band 501, and a higher frequency band is dedicated to downstream communication, the downstream band 503. The downstream band 503 may

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partially or completely overlap the upstream band 501. Other DSL schemes may consist of the same number or more upstream and downstream bands of possibly varying bandwidths that may be interleaved and may be partially or fully overlapped. Such spectral schemes can be extended to the present embodiment. During standard G.lite operations, the upstream band is used for data transmission from an ATU-R to an ATU-C and the downstream band is used for data transmission from an ATU-C to an ATU-R. The G.lite upstream band is typically from about 26 KHz to 138 KHz and the downstream band from 138 KHz to 552 KHz.

To simultaneously transmit and receive between an ATU-R initiator and an ATU-R responder, a duplex transmission channel is necessary. Preferred embodiments for the home network physical layer signaling use the existing G.lite upstream frequency spectrum to transmit and receive home networking data. This is advantageous because existing G.lite equipment already have the hardware capability to transmit in this frequency spectrum, thus leveraging the use of existing G.lite equipment. However, in order to receive home networking signals in the lower frequencies, the G.lite modems should also be capable of receiving in the upstream frequency spectrum. This should be the case for those G.lite modems that do not use very sharp analog FDM (frequency domain multiplexing) filtering for the upstream and downstream frequency band separation. In addition, by reusing the upstream frequency spectrum, the spectral mask of the G.lite ATU-R will not be exceeded, ensuring spectral compatibility with other existing and future equipment. The existing equipment must therefore be capable of both transmitting and receiving within the same frequency band. Echo canceling capable DSL equipment is exemplary of such equipment capable of both transmitting and receiving in the same frequency band and is thus part of the preferred embodiment.

Figures 4a and 4b show embodiments of home networking signaling using time-domain channel separation over a shared frequency band. Both the home networking ATU-R initiator

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("HATU-i") and the home networking ATU-R responder ("HATU-r") transmit and receive on the same G.lite upstream frequency band 601 as shown in Figure 4a. The G.lite downstream band 603 is not used, however, a preferred embodiment should monitor the downstream band for any central office DSL initiation signals. As seen in Figure 4a, to facilitate bi-directional communications two streams sharing the same frequency band are used. The first is the Homestream-i 605 to facilitate communications between the HATU-i initiator and the HATU-r responder, and the second is the Homestream-r to facilitate communications between the HATU-r responder and the HATU-i initiator. In transmission, the ATU-R initiator will transmit using Homestream-i 605 and wait after each transmission. In reception, the ATU-R initiator, while waiting a guard time 609 after transmission will receive from Homestream-r 607 on the same frequency band. The duration of the guard time 609 need not be equal or fixed and may be of zero time duration, so long as the Homestream-i and Homestream-r are capable of separating their transmissions from receptions. The downstream band 603 is unused, however, it should be monitored for G.hs or other initialization signals.

Another embodiment where home network signaling is assisted by frequency domain channel separation is illustrated in Figure 5. The existing G.lite downsteam band 701 is unused, however, it should be understood that a preferred embodiment should continue to monitor the downstream band for any central office or ATU-C initiated activity. The G.lite upstream frequency band is separated into two frequency bands, one for use with Homestream-i 703 and another for use with Homestream-r 705. Both homestreams can therefore transmit and receive independent of each other. The band separation point 707 can be changed to provide different bandwidths for different communication needs. It should be understood that the ordering of the bands is immaterial. The downstream band 701 is unused, but again should be monitored for G.hs or other initialization signals.

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In yet another embodiment, home network signaling uses an overlapped spectrum with channel separation by echo canceling. In Figure 6, the existing G.lite downstream band 801 is once again unused, again it should also be understood that however, a preferred embodiment should monitor the downstream band for central office initiated activity. The original G.lite upstream band of this embodiment occupied by both Homestream-i and Homestream-r which overlap in frequency. The portion of the bandwidth associated with Homestream-i 803 and that of Homestream-r 805 can be partially or fully overlapped. It should be understood that if only partially overlapped, the ordering of the bands is immaterial and may vary. Because both ATU-Rs are simultaneously transmitting on the same frequency, the received signal at either modem will be the sum of what that modem transmitted and the desired signal that the other modem transmitted. Since the modem knows what it transmitted, it subtracts its own transmissions from the received signal to be left with only the desired signal. The downstream band 801 is unused.

Another embodiment for home network signaling uses the full G.lite spectrum. As illustrated in Figure 7, the Homestream-i is transmitted over the existing G.lite upstream band 901, about 26 KHz to 138 KHz, and Homestream-r is sent over the existing G.lite downstream band 903, 138 KHz to 552 KHz or vice versa. It should be understood that it is immaterial which stream is sent over which band. Indeed, it should also be understood that the entire frequency spectrum need not be used and each frequency band may be altered accordingly. Furthermore, the band separation point need not correspond with the frequency separation point of G.lite (i.e., 138 KHz).

In contrast to other embodiments, this embodiment provides increased data rates due to the greater bandwidth utilized. This embodiment, however, implies a violation of the G.lite ATU-R transmit spectrum that may impact other systems sharing the binder group to the CO due to crosstalk. Potential crosstalk problems may be alleviated by decreasing the transmit power in

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the downstream band for home networking, at the cost of data throughput. For example, by limiting the home networking transmit power in the downstream band to some small amount greater than the received downstream signal from the CO, the crosstalk into the loop plant will be no greater that if the central office was transmitting. Even with such power limitations the data rate in the home networking mode should still be similar to that for G.lite mode. For the case where the CO is active in a home networking session, the standard DSL band allocation and power levels may be used without violating the G.lite PSD masks.

Other DSLs have similar PSD mask considerations in that the PSD masks used for home networking should be constrained by the PSD mask of the DSL service provisioned at the central office. Furthermore, when transmitting in a band used normally to receive a DSL service, the transmit level used for home networking should ideally reflect the received level in that band measured during normal DSL service.

The present embodiments allow computer devices within a customer premise to communicate over a home network at a minimal incremental cost by leveraging the use of existing DSL equipment. The use of G.hs protocols and the DSL frequency spectrum for home networking when the DSL connection is not present or in an idle state allows for the efficient reuse of the DSL hardware. Central office and CPE initiated DSL connections are also monitored for the initiation of DSL connections. Providing DSL modems with home network capability allows the addition of network capability at a minimal cost. The initial cost of providing a network within the home is reduced and made more accessible to more homes.

In view of the wide variety of embodiments to which the principles of the present embodiments can be applied, it should be understood that the illustrated embodiments are exemplary only. The illustrated embodiments should not be taken as limiting the scope of the present invention.

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The claims should not be read as limited to the described order of elements unless stated to that effect. In addition, use of the term "means" in any claim is intended to invoke 35 U.S.C. §112, paragraph 6, and any claim without the word "means" is not so intended. Therefore, all embodiments that come within the scope and spirit of the following claims and equivalents thereto are claimed as the invention.

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